

## CLAIMS

1. A method comprising:

managing a multi-dimensional sleep queue, the managing comprising:

inserting a thread into the multi-dimensional sleep queue; and

removing the thread from the multi-dimensional sleep queue.

2. A method as recited in claim 1, wherein the multi-dimensional sleep queue is a real-time multi-dimensional sleep queue.

3. A method as recited in claim 1, wherein the multi-dimensional sleep queue is a two-dimensional sleep queue.

4. A method as recited in claim 1, wherein inserting a thread into the multi-dimensional sleep queue is performed in a manner that allows a thread scheduling mechanism to schedule other threads for execution within a deterministic amount of time.

5. A method as recited in claim 1, wherein inserting a thread into the multi-dimensional sleep queue further comprises:

inserting the thread into the multi-dimensional sleep queue such that a group of threads can be removed from the multi-dimensional sleep queue in a deterministic amount of time.

1           6.     A method as recited in claim 1, wherein the multi-dimensional sleep  
2 queue comprises a group of threads, and wherein the method further comprises:  
3           removing the group of threads from the multi-dimensional sleep queue in a  
4 deterministic amount of time, each thread in the group having a same wake-up  
5 time.

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7           7.     A method as recited in claim 1, wherein the thread has a wake-up  
8 time and a priority; and

9           wherein inserting the thread into the multi-dimensional sleep queue further  
10 comprises:

11           sorting the thread with respect to a first dimension of threads and a  
12 second dimension of threads, the first dimension of threads being sorted based on  
13 respective thread wake-up times, the second dimension of threads being sorted  
14 based on respective thread priorities, the thread being sorted first with respect to  
15 the first dimension and second with respect to the second dimension.

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17           8.     A method as recited in claim 7, wherein the first dimension of threads  
18 comprises a plurality of threads, each thread in the first plurality having a different  
19 respective thread wake-up time.

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21           9.     A method as recited in claim 7, wherein the second dimension of  
22 threads comprises a plurality of threads, each thread in the second plurality having  
23 a same respective thread wake-up time.

1           **10.**     A method as recited in claim 7, wherein the thread is a new thread,  
2 and wherein sorting the thread further comprises:

3                 determining that a wake-up time corresponding to the new thread is  
4 different as compared to each respective wake-up time of each other thread in the  
5 first dimension of threads; and

6                 responsive to the determining, introducing the new thread into the first  
7 dimension of threads.

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9           **11.**     A method as recited in claim 7, wherein sorting the thread further  
10 comprises:

11                 identifying a different thread in the first dimension of threads that has a  
12 same wake-up time as the new thread wake-up time; and

13                 responsive to identifying the different thread:

14                         concluding that a first priority corresponding to the new thread  
15 priority is higher than a second priority corresponding to the different thread; and

16                         replacing the different thread in the first dimension with the new  
17 thread, such the new thread is a member of both the first and the second  
18 dimensions of threads, and such that the replaced thread has a secondary position  
19 with respect to the first and second dimensions of threads.

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21           **12.**     A method as recited in claim 7, wherein sorting the thread further  
22 comprises:

23                 identifying a different thread in the first dimension of threads that has a  
24 same wake-up time as the new thread wake-up time;

25                 responsive to identifying the different thread:

1 determining that a first priority corresponding to the new thread is  
2 lower than a second priority that corresponds to the different thread; and  
3 inserting the new thread into the second dimension of threads, such  
4 the new thread occupies a secondary position with respect to the first and second  
5 dimensions of threads.  
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7 **13.** A computer-readable medium comprising computer-executable  
8 instructions for:

9 managing a multi-dimensional sleep queue, the instructions for managing  
10 comprising:

11 inserting a thread into the multi-dimensional sleep queue; and  
12 removing the thread from the multi-dimensional sleep queue.  
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14 **14.** A computer-readable medium as recited in claim 13, wherein the  
15 multi-dimensional sleep queue is a real-time multi-dimensional sleep queue.  
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17 **15.** A computer-readable medium as recited in claim 13, wherein the  
18 instructions for inserting a thread into the multi-dimensional sleep queue are  
19 performed in a manner that allows a thread scheduling mechanism to schedule  
20 other threads for execution in a deterministic amount of time.  
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1           **16.**    A computer-readable medium as recited in claim 13, wherein the  
2 instructions for inserting a thread into the multi-dimensional sleep queue further  
3 comprise instructions for:

4                   inserting the thread into the multi-dimensional sleep queue such that  
5 a group of threads can be removed from the multi-dimensional sleep queue in a  
6 deterministic amount of time.

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8           **17.**    A computer-readable medium as recited in claim 13, wherein the  
9 multi-dimensional sleep queue comprises a group of threads, and wherein the  
10 computer-executable instructions further comprise instructions for:

11                   removing the group of threads from the multi-dimensional sleep queue in a  
12 deterministic amount of time, each thread in the group having a same wake-up  
13 time.

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15           **18.**    A computer-readable medium as recited in claim 13, wherein the  
16 thread has a wake-up time and a priority; and

17                   wherein the instructions for inserting the thread into the multi-dimensional  
18 sleep queue further comprise instructions for:

19                    sorting the thread with respect to a first dimension of threads and a  
20 second dimension of threads, the first dimension of threads being sorted based on  
21 respective thread wake-up times, the second dimension of threads being sorted  
22 based on respective thread priorities, the thread being sorted first with respect to  
23 the first dimension and second with respect to the second dimension.

1           **19.**    A computer-readable medium as recited in claim 18, wherein the  
2 first dimension of threads comprises a plurality of threads, each thread in the first  
3 plurality having a different respective thread wake-up time.

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5           **20.**    A computer-readable medium as recited in claim 18, wherein the  
6 second dimension of threads comprises a plurality of threads, each thread in the  
7 second plurality having a same respective thread wake-up time.

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9           **21.**    A computer-readable medium as recited in claim 18, wherein the  
10 thread is a new thread, and wherein the instructions for sorting the thread further  
11 comprise instructions for:

12               determining that a wake-up time corresponding to the new thread is  
13 different as compared to each respective wake-up time of each other thread in the  
14 first dimension of threads; and

15               responsive to the determining, introducing the new thread into the first  
16 dimensions.

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18           **22.**    A computer-readable medium as recited in claim 18, wherein the  
19 instructions for sorting the thread further comprise instructions for:

20               identifying a different thread in the first dimension of threads that has a  
21 same wake-up time as the new thread wake-up time; and

22               responsive to identifying the different thread:

23               concluding that a first priority corresponding to the new thread  
24 priority is higher than a second priority corresponding to the different thread; and  
25

1 replacing the different thread in the first dimension with the new  
2 thread, such the new thread is a member of both the first and the second  
3 dimensions of threads, and such that the replaced thread has a secondary position  
4 with respect to the first and second dimensions of threads.  
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6 **23.** A computer-readable medium as recited in claim 18, wherein the  
7 instructions for sorting the thread further comprise instructions for:

8 identifying a different thread in the first dimension of threads that has a  
9 same wake-up time as the new thread wake-up time;

10 responsive to identifying the different thread:

11 determining that a first priority corresponding to the new thread is  
12 lower than a second priority that corresponds to the different thread; and

13 inserting the new thread into the second dimension of threads, such the new  
14 thread occupies a secondary position with respect to the first and second  
15 dimensions of threads.  
16

17 **24.** A method for managing a multi-dimensional sleep queue  
18 comprising:

19 inserting a new thread into the multi-dimensional sleep queue using a  
20 multi-dimensional atomic walk procedure; and

21 removing the new thread from the multi-dimensional sleep queue for  
22 insertion into a run queue.  
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1           **25.**    A method as recited in claim 24, wherein inserting the new thread  
2 further comprises:

3           if the new thread is a first thread, setting a last examined thread to reference  
4 the new thread, the last examined thread being used to identify an insertion point  
5 for the new thread.

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7           **26.**    A method as recited in claim 24, further comprising:  
8 removing a group of threads from the multi-dimensional sleep queue in a  
9 deterministic amount of time.

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11          **27.**    A method as recited in claim 24, further comprising:  
12 removing a group of threads from the sleep queue in a deterministic amount  
13 of time, each thread in the group of threads having a same wake-up time.

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15          **28.**    A method as recited in claim 27, wherein the deterministic amount  
16 of time is independent of a number of threads in the group of threads.

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18          **29.**    A method as recited in claim 24, wherein the multi-dimensional  
19 sleep queue comprises at least one other thread, and wherein inserting the new  
20 thread further comprises:

21           establishing a thread insertion point in the multi-dimensional sleep queue  
22 for the new thread; and

23           introducing the new thread into the multi-dimensional sleep queue at the  
24 insertion point.



1           **30.**    A method as recited in claim 29, wherein establishing the thread  
2 insertion point further comprises:

3           determining if a status of a last examined thread has changed, the status  
4 indicating either that the last examined thread was removed from the multi-  
5 dimensional sleep queue, or indicating that the last examined thread was moved  
6 from a first dimension of threads that is sorted based on respective thread wake-up  
7 times, to a second dimension of threads that is ordered based on respective thread  
8 priorities;

9           if the status of the last examined thread has changed, searching for the  
10 thread insertion point from a beginning of the multidimensional sleep queue; and

11          if the status of the last examined thread has not changed, searching for the  
12 thread insertion point from the last examined thread.

13  
14           **31.**    A computer-readable medium comprising computer-executable  
15 instructions for managing a sleep queue, the computer executable instructions  
16 comprising instructions for:

17          inserting a new thread into the sleep queue using a multi-dimensional  
18 atomic walk procedure; and

19          removing the new thread from the sleep queue for insertion into a run  
20 queue.

1           **32.**    A computer-readable medium as recited in claim 31, wherein  
2 instructions for inserting the new thread further comprise instructions for:

3            if the new thread is a first thread, setting a last examined thread to reference  
4 the new thread, the last examined thread being used to identify an insertion point  
5 for the new thread.

6  
7           **33.**    A computer-readable medium as recited in claim 31, further  
8 comprising instructions for:

9            removing a group of threads from the sleep queue in a deterministic amount  
10 of time.

11  
12           **34.**    A computer-readable medium as recited in claim 31, further  
13 comprising instructions for:

14            removing a group of threads from the sleep queue in a deterministic amount  
15 of time, each thread in the group of threads having a same wake-up time.

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17           **35.**    A computer-readable medium as recited in claim 34, wherein the  
18 deterministic amount of time is independent of a number of threads in the group of  
19 threads.

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21           **36.**    A computer-readable medium as recited in claim 31, wherein the  
22 multi-dimensional sleep queue comprises at least one other thread, and wherein  
23 the instructions for inserting the new thread further comprise instructions for:

24            establishing a thread insertion point in the multi-dimensional sleep queue  
25 for the new thread; and

1 introducing the new thread into the multi-dimensional sleep queue at the  
2 insertion point.

3  
4 **37.** A computer-readable medium as recited in claim 36, wherein the  
5 instructions for establishing the thread position further comprise instructions for:

6 determining if a status of a last examined thread has changed, the status  
7 indicating either that the last examined thread was removed from the multi-  
8 dimensional sleep queue, or indicating that the last examined thread was moved  
9 from a first dimension of threads that is sorted based on respective thread wake-up  
10 times, to a second dimension of threads that is ordered based on respective thread  
11 priorities;

12 if the status of the last examined thread has changed, searching for the  
13 thread insertion point from a beginning of the multidimensional sleep queue; and

14 if the status of the last examined thread has not changed, searching  
15 for the thread insertion point from the last examined thread.

16  
17 **38.** A computer comprising one or more computer-readable media as  
18 recited in claim 31.

19  
20 **39.** A system for managing a sleep queue, the system comprising:

21 a memory comprising computer-executable instructions and a multi-  
22 dimensional sleep queue;

23 a processor operatively coupled to the memory for executing the computer-  
24 executable instructions, the computer-executable instructions comprising  
25 instructions for:

1 inserting a thread into a multi-dimensional sleep queue; and  
2 removing the thread from the multi-dimensional sleep queue.  
3

4 **40.** A system as recited in claim 39, wherein the multi-dimensional  
5 sleep queue is a real-time multi-dimensional sleep queue.  
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7 **41.** A system as recited in claim 39, wherein the instructions for  
8 inserting the thread are performed in a manner that allows a thread scheduling  
9 mechanism to schedule other threads for execution in a deterministic amount of  
10 time.  
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12 **42.** A system as recited in claim 39, wherein the instructions for  
13 inserting the thread further comprise instructions for:  
14

15 inserting the thread into the multi-dimensional sleep queue such that a  
16 group of threads can be removed from the multi-dimensional sleep queue in a  
17 deterministic amount of time.  
18

19 **43.** A system as recited in claim 39, wherein the multi-dimensional  
20 sleep queue further comprises a group of threads, and wherein the  
21 computer-executable instructions further comprise instructions for:  
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23 inserting the group of threads into the multi-dimensional sleep queue; and  
24 removing the group of threads from the multi-dimensional sleep queue in a  
25 deterministic amount of time, each thread in the group having a same wake-up  
time.

1           **44.**     A system as recited in claim 39, wherein the thread has a wake-up  
2 time and a priority, and wherein the instructions for inserting the thread further  
3 comprise instructions for:

4                 sorting the thread with respect to a first dimension of threads and a second  
5 dimension of threads, the first dimension of threads being sorted based on  
6 respective thread wake-up times, the second dimension of threads being sorted  
7 based on respective thread priorities, the thread being sorted first with respect to  
8 the first dimension and second with respect to the second dimension.

9  
10           **45.**     A system as recited in claim 44, wherein the first dimension of  
11 threads comprises a plurality of threads, each thread in the first plurality having a  
12 different respective thread wake-up time.

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14           **46.**     A system as recited in claim 44, wherein the second dimension of  
15 threads comprises a plurality of threads, each thread in the second plurality having  
16 a same respective thread wake-up time.

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18           **47.**     A system as recited in claim 44, wherein the thread is a new thread,  
19 and wherein the instructions for sorting the thread further comprise instructions  
20 for:

21                 determining that a wake-up time corresponding to the new thread is  
22 different as compared to each respective wake-up time of each other thread in the  
23 first dimension of threads; and

24                 responsive to determining that the wake-up time is different, introducing  
25 the new thread into the first dimension of threads.

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2       **48.**     A system as recited in claim 44, wherein the instructions for sorting  
3 the thread further comprise instructions for:

4       identifying a different thread in the first dimension of threads that has a  
5 same wake-up time as the new thread wake-up time; and

6       responsive to identifying the different thread:

7       concluding that a first priority corresponding to the new thread  
8 priority is higher than a second priority corresponding to the different thread; and

9       replacing the different thread in the first dimension with the new  
10 thread, such the new thread is a member of both the first and the second  
11 dimensions of threads, and such that the replaced thread has a secondary position  
12 with respect to the first and second dimensions of threads.

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14       **49.**     A system as recited in claim 44, wherein the instructions for sorting  
15 the thread further comprise instructions for:

16       identifying a different thread in the first dimension of threads that has a  
17 same wake-up time as the new thread wake-up time;

18       responsive to identifying the different thread:

19       determining that a first priority corresponding to the new thread is  
20 lower than a second priority that corresponds to the different thread; and

21       inserting the new thread into the second dimension of threads, such the new  
22 thread occupies a secondary position with respect to the first and second  
23 dimensions of threads.

1           **50.**     A sleep queue data structure comprising:  
2           a first dimension data field for queuing threads based on wake-up time; and  
3           a second dimension data field for queuing threads based on priority within a  
4 particular wake-up time.

5  
6           **51.**     A sleep queue data structure as recited in claim 50, wherein the first  
7 and second data fields are configured with respect to one another such that a  
8 thread scheduling mechanism can remove a group of threads from the sleep queue  
9 data structure in a determinative amount of time.

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11           **52.**     A sleep queue data structure as recited in claim 50, wherein  
12 determinative amount of time is independent of a number of threads in the group  
13 of threads.

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15           **53.**     A sleep queue data structure as recited in claim 50, wherein the first  
16 and second dimension data fields further comprise:  
17           a thread data field comprising:  
18                 a wake-up time data field; and  
19                 a priority data field;

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21           **54.**     A sleep queue data structure as recited in claim 50, wherein the  
22 sleep queue data structure is a linked list sleep queue data structure.  
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1           **55.**    A sleep queue data structure as recited in claim 50, wherein the  
2 sleep queue data structure is configured such that a thread can be inserted into the  
3 sleep queue data structure using a multi-dimensional atomic walk procedure.  
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5           **56.**    A computer-readable medium comprising a data structure as recited  
6 in claim 50.  
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